SOCIAL BEHAVIOUR OF THE AXIS DEER DURING THE DRY SEASON IN GUINDY SANCTUARY, MADRAS[1]

SHINGO MIURA[2]

(*With three text-figures*)

The social behaviour of the axis deer is described. Axis deer exhibit a biomodal pattern in diurnal activity, changing their grouping behaviour and vegetative use. Several separate elements are identified in buck-buck and doe-buck interactions respectively. Axis deer make no attempt to form a harem group, nor do they establish territory. Brief comparisons are made between social behaviour of axis and certain other cervids.

Although the axis deer *Axis axis* can generally be found in moist and dry deciduous forests, practically throughout peninsular India (Prater 1971), the eco-ethological study made by Schaller (1967) was only for Kanha population, in Central India. I had an opportunity to visit Guindy Sanctuary, South India from 29th February to 2nd April, 1977 and was able to gather quantitative data concerning grouping and rutting behaviour of the axis deer. The purpose of this study is to describe social behaviour and to determine the social system of the axis deer during the dry season as it compared to other populations and to other cervids.

STUDY AREA AND METHOD

Guindy Sanctuary covers an area of 302 ha of flat terrain and is located at the outskirts of Madras City, Tamil Nadu. This small sanctuary is rich in wildlife, e.g. axis deer, blackbuck (*Antilope cervicapra*), bonnet macaque (*Macaca radiata*), and common mongoose (*Herpestes edwardsi*).

According to a direct census carried out by the Madras Wildlife Warden in May of 1976, the population of deer and blackbuck was 1360 animals (density ; 4.5 animals/ha.) and 740 animals (2.4 animals/ha.) respectively. These densities are considerably higher than other populations (see ; Sharatchandra and Gadgil 1977).

I roughly divided the vegetation of this area into three types as follows : (1) deciduous thorny forest dominated by *Acacia planifrons*, *Acacia leucophloea*, *Acacia javanica*, *Azadirachta indica* and *Derris glabra* (covering with 44% of the area), (2) mixed forest with *Ficus bengalensis*, *Atlantia monosperma*, and *Glycosmis pentaphylla* (33%), and (3) grassland (23%). Due to overbrowsing by ungulates, some malformed palatable plants, such as *Plugia leucophrus*, *Carissa spinarum*, and *Randia* spp. occurred in the area.

More than 250 hrs. of direct observations on the deer were made along standardized routes in the area. Use of 9 × 35 binoculars facilitated the identification of sex, size, and behavioural acts of the deer. Antlered bucks were classified into five antler classes as ' spikes ', less than 40 cm, 41-50 cm, 51-60 cm, and more than 61 cm. Social interactions and behavioural acts were recorded in field note on a minute-by-minute basis, noting sex, antler class, and when possible, known animals. More than 30 animals of both sexes were recognized as individuals by antler configuration, and by distinctive marks such as natural notches at ear

---

[1] Accepted August 1979.

[2] Laboratory of Biology, Hyogo College of Medicine, Nishinomiya, Hyogo, Japan.

margins and scars in various regions. Some individuals were recorded as many as 25 times. Based upon the description by Hardin *et al.* (1977), I observed whether the deer formed a group or not. The deer were regarded as a herd when they were within view of one another and responding to each other during the entire period of observation. However, some cases, were not considered as a group as even though they were adjacent to one another, they went their separate ways after brief interactions.

RESULTS AND DISCUSSION

Out of a total number of 6318 individuals, 3789 (60.0%) were adult or juvenile does, 1425 (22.6%) were bucks including yearlings and 1101 (17.4%) fawns. The buck to doe ratio, based on above data, was 35.0 : 100.0. Most bucks (82.2%) were with hard antlers, 17.2 per cent were in velvet, and the rest had shed their antlers.

GROUP SIZE AND COMPOSITION

Out of 2424 total observation records, 880 (36.3%) were of single animals and 1546 (63.7%) were groups of two or more or herds. The overall average group size was 2.83 (range; 1-37 animals). The distribution of herd sizes is skewed toward small groups, with 85.6 per cent of all groups containing fewer than four deer. The percentage of all deer seen in groups of various sizes, however, is considerably larger in larger groups : 44 per cent of all deer were in groups of five or more.

Doe groups, consisting only of females with or without fawns, were observed more frequently than mixed and buck only groups. Strong social ties appeared to exist between does, and between doe and fawn. Most (89.3%) of the 1526 sightings of groups numbering two or three were doe groups. Although the composition of groups of more than four was generally mixed (56.7%), the frequency of doe groups observed should not be ignored (39.9%). Few buck groups consisting of males only were seen during this period : most bucks were seen either as solitary (26.0% of all bucks) or as members of a mixed group (63.0%).

DIURNAL RHYTHMS

Diurnal rhythms of the axis were examined from 0600 to 1900 hrs from three points of view: vegetative use, basic activities, and grouping behaviour.

Percentages of deer observed in the three vegetation types to every one hour are presented in Fig. 1A. This indicates a certain pattern of diurnal vegetative use of the deer. In the grassland which is characterized by an open habitat rich in food for grazing, there were two peaks; in the early morning between 0600 and 0700 hrs and in the evening between 1600 and 1700 hrs, and there was one lull in the daytime between 1100 and 1200 hrs. The Deciduous forest which was dominant in the area and was characterized by relatively open habitat poor in food, was consistently used to some degree during all of the observations, but this was rather used frequently during the midday. Use of mixed forest, which was characterized by closed habitat and relatively rich in food for browsing, was the inverse of the use of grassland. There was one peak at midday of 1100-1200 hrs. These changes of vegetative use may be closely related with their diurnal activities.

I divide here the acts of the animals into four basic categories; resting (lying on the ground), feeding (grazing and/or browsing), moving, and others (grooming, suckling, drinking, and social acts etc.). Percentages of these acts to every one hour are shown in Fig. 1B. Axis exhibit a biomodal activity pattern. There were two peaks and one lull in feeding. The morning peak between 0600 and 0700 hrs, 89 per cent of animals

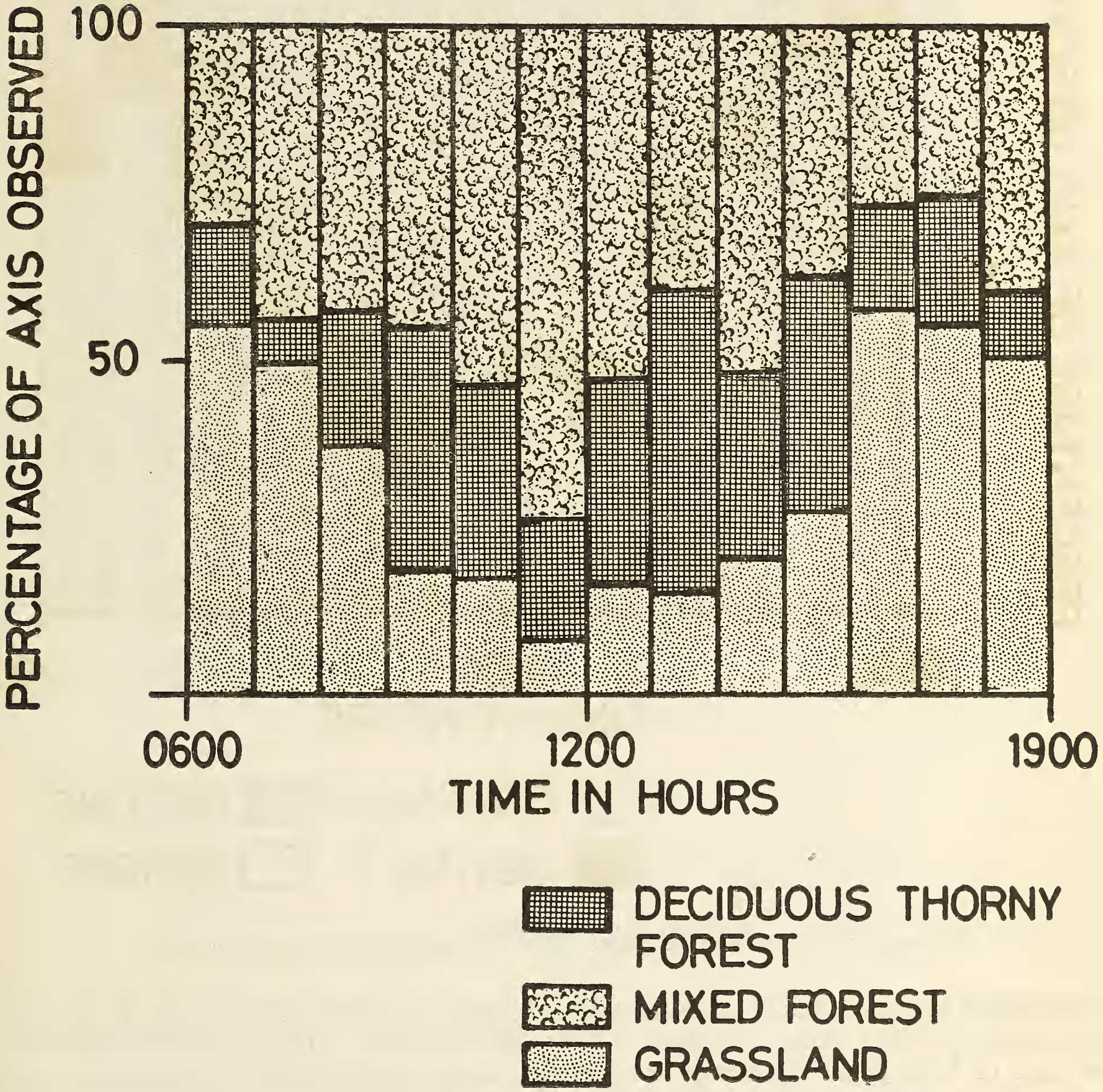

Fig. 1A. Percentages of the axis deer observed in three vegetation types per hour in Guindy Sanctuary.

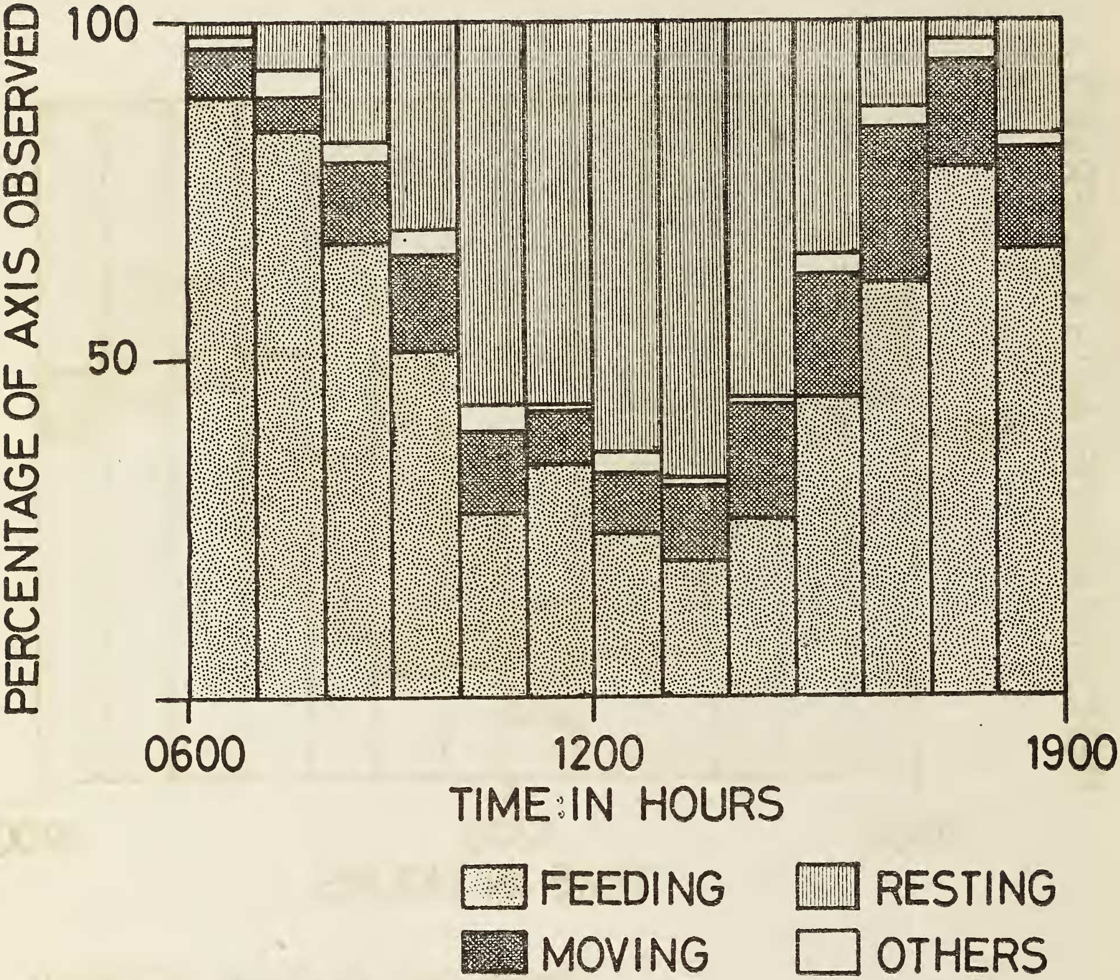

Fig. 1B. Percentages of four basic acts of the axis deer observed per hour in Guindy Sanctuary.

were engaged in feeding, and during the evening peak between 1700 and 1800 hrs, 78 per cent. The per cent of feeding was apparently inversely proportional to resting. The lull of feeding was coincident with the peak of resting. Moving was consistently observed all the time with slight increases before and after the peaks of feeding. It was noticeable that the two peaks for feeding synchronized with the peaks for the use of the grassland and the peak for resting was also roughly coincident with the peak for the use of the mixed forest. Diurnal changes of their activities may deeply influence grouping behaviour.

Percentages of various group sizes observed every hour including average group size observed every hour are presented in Fig. 1C. Single animal and groups of two animals were observed all the time with ranges of 21-49 per cent, and 20-42 per cent respectively. But, both occurred more frequently in the daytime between

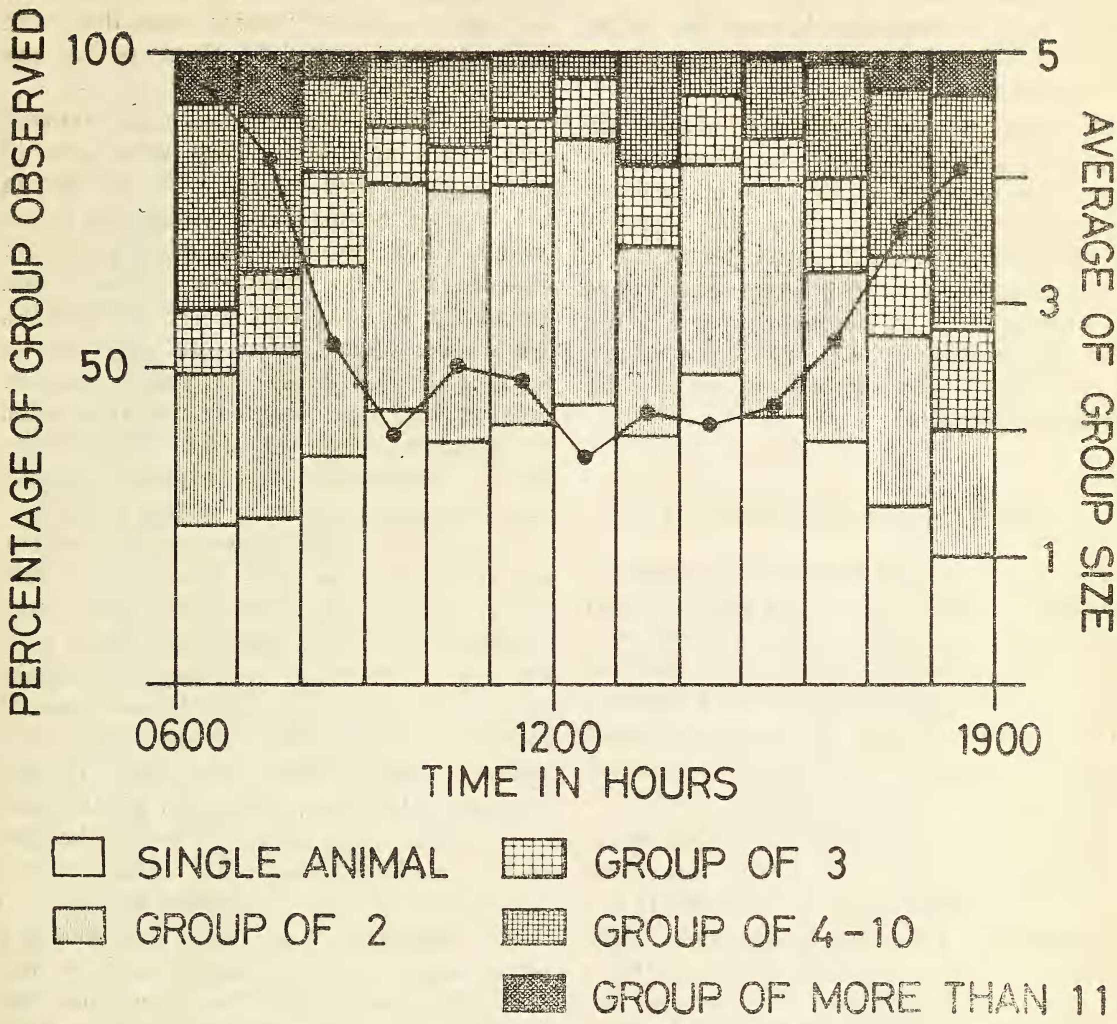

Fig. 1C. Frequencies of various sizes of groups observed per hour, including average sizes of groups, in Guindy Sanctuary.

0900 and 1600 hrs than in the early morning and in the evening. On the contrary, groups of 3-10 animals occurred more frequently in the early morning and in the evening than during the daytime. Out of 72 total sightings of large sized groups of more than 11 animals, only seven were seen during the daytime between 0900 and 1600 hrs. The largest group of 37 animals were engaged in grazing and moving in the grassland between 1608 and 1619 hrs. Changes of the average size of the groups shows a 'V' shape curve, which indicates that larger gathering tended to occur more often in the morning and in the evening than during midday. Thus, it is reasonable to infer that after the early morning the animals split up their organization into smaller groups or solitary, and in the evening they reorganized and formed into larger groups, while changing their activities and use of vegetation.

My observations after 1900 hrs indicate that almost all members (85.6%) rested, and they should be regarded as the roosting groups. Similar large roosting groups were also observed for Sika deer at Nara Park, Japan (Miura 1975). It is evident that the larger groups observed in the evening were in the process of forming roosting aggregations, and the larger groups in the morning were the breaking up of these roosting aggregations.

STABILITY OF KNOWN INDIVIDUALS

The organization of the axis deer is characterized not by fixed but a rather flexible system that changes from morning till night with relation to their diurnal activities. To illustrate this aspect of the social organization I tabulated all observations of some of known individuals sighted frequently. Five selected examples of these records are given in Tables 1 and 2.

Table 1 gives data on 47 total sightings of three does. Two (F1 and F2) of them were considered as mothers rearing newborns (11 and 12) respectively from suckling behaviour. The mothers were seen in various group sizes numbering 1 to 34 individuals. There was no evidence indicating a firm bond between them and other adult or juvenile individuals except their fawns. Of the 33 total sightings of the mothers, they were seen 20 times with their fawns. Of the 11 occasions they were in groups of two animals, they almost always (90.9%) associated with their fawns. The data on mothers, therefore, indicate that the family bond, composed of a doe and her fawns must be regarded as a very stable unit (Graf and Nichols 1966, Schaller 1967, Eisenberg and Lockhart 1972). F9 was also seen in various sized groups of 1-34 animals. Does associated more often with other adult or juvenile does than with bucks, although there did not seem to exist any special ties between does.

Table 2 lists 38 total sightings of two antlered bucks (M1 and M9). They were seen in various group sizes ranging 1-30, and also in two types of groups ; buck groups and mixed groups. They were seen with mixed groups for 68.4 per cent of the observation, and with buck groups for 10.3 per cent of the observations. While they often herded with other known bucks (M6 and M14), no special contacts between them were observed : the organization among bucks became very weak once they were in rut. Presumably, they happened to join same associations is search of does in oestrus.

Normally the relation between buck and doe was transitory : the buck would try to sniff at her perineal region and then move away indifferently from her, unless she was in heat, and this contact usually lasted only a few seconds. But, if she was in heat, the buck would attempt to follow or to remain with her tenaciously, probably until mating was over. F9 was accompanied at least three days by M28 and other bucks. When she was in heat on the 22nd of March, M28 showed sexual interest towards her and escorted her throughout the observation. The next day, after they were seen in a large association, she separated from this association and entered the forest and was followed by three bucks including M28. Copulation probably occurred on this day. Afterwards, she was not followed by any of the bucks including M28, though they were observed twice in the same association.

The family bond appears to be the basic unit of the group and all other kinds of groups or aggregations observed may be made up of several family parties and solitaries which may come together temporarily, an observation which agrees with those of Graf and Nichols (1966) and Schaller (1967). Thus, although

TABLE 1

GROUPING BEHAVIOUR AND COMPOSITION: ALL OBSERVATIONS OF F1, F2, AND F9. FIGURES IN PARENTHESES INDICATE INDIVIDUAL NUMBER OF KNOWN ANIMALS

No.	Date	Adult bucks	Juvenile bucks	Adult females	Juvenile females or fawns	Group size
F 1						
1	9/3				1 (I1)	2
2	10/3			1	1 (I1)	3
3	11/3	1			1	3
4	12/3		1	2	2 (I1)	6
5	13/3					1
6	14/3					1
7	15/3				2 (I1)	3
8	16/3			1	3 (I1)	5
9	17/3				1 (I1)	2
10	18/3			2	2 (I1)	5
11	19/3	1		2	2	6
12	20/3				1 (I1)	2
13	24/3	1			1	3
14	25/3				1 (I1)	2
15	26/3				1	2
16	27/3			1	2	4
17	28/3			1	1 (I1)	3
18	29/3				1	2
19	30/3	3	1	5	2 (I1)	12
20	31/3				1 (I1)	2
21	1/4				1 (I1)	2
F 2						
1	11/3					1
2	12/3			2	2 (I2)	5
3	1/73		1	2	2	6
4	19/3				1 (I2)	2
5	20/3				1 (I2)	2
6	22/3				1 (I2)	2
7	25/3			1	1	3
8	26/3	3	1	13 (F9)	16 (I2)	34
9	27/3			1	1	3
10	28/3	2	2	5	2 (I2)	12
11	29/3			2	2 (I2)	5
12	30/3			1	1	3
F 9						
1	14/3			4	5	10
2	15/3				1	2
3	19/3				2	3
4	20/3					1
5	21/3			11	11	23
6	22/3	1 (M28)		4	6	12
7	23/3	3 (M28, M25)		13	11	28
8	24/3	1 (M28)		12	11	25
9	25/3	1 (M29)		1	1	4
10	26/3	3 (M25, M28, M29)	1	13 (F2)	16	34
11	27/3			1	1	3
12	28/3	1				2
13	29/3				1	2
14	30/3				1	2

TABLE 2

GROUPING BEHAVIOUR AND COMPOSITION : ALL OBSERVATIONS OF M1 AND M9. FIGURES IN PARENTHESES INDICATE INDIVIDUAL NUMBERS OF KNOWN ANIMALS

No.	Date	Adult bucks	Juvenile bucks	Adult females	Juvenile females or fawns	Group size
M 1						
1	8/3			2	2	3
2	9/3	2 (M11, M26)			1	4
3	10/3	1				2
4	11/3			1	4	6
5	13/3	2 (M6, M7)		2	2	7
6	14/3					1
7	15/3	1 (M11)		2		4
8	16/3	1 (M11)				2
9	20/3					1
10	22/3			3	2	6
11	23/3	1 (M6)		3	5	10
12	24/3			1	1	3
13	25/3	1 (M6)		2	1	5
14	26/3	1 (M6)		3	2	7
15	27/3	3 (M8)	2	8 (F6)	5	19
M 9						
1	8/3	2 (M3, M18)		1		4
2	9/3	4 (M10, M11)		3	4	13
3	10/3	4 (M10, M11)		2	1	8
4	11/3	7 (M10, M14, M18)	1	4 (F8)	4	17
5	12/3	1		1	2	5
6	13/3					1
7	14/3	6 (M3, M13, M14, M18, M27)	1	3	5	16
8	15/3			3	1	5
9	16/3					1
10	17/3	5 (M14, M18, M22, M27)		4	4	14
11	18/3	5 (M14, M22, M27)	1	6 (F5, F8)	6	19
12	19/3			1	1	3
13	20/3	1		4	1	7
14	22/3	11 (M2, M3, M14, M27)	1	10 (F5)	7	30
15	23/3			1	1	3
16	24/3	5 (M15)		9	7	22
17	25/3	3 (M14)		4	1	9
18	26/3					1
19	27/4					1
20	28/3	1		3 (F8)	2	7
21	29/3					1
22	30/3	1				2
23	31/3					1

grouping behaviour of the axis deer is, indeed, highly developed, the basic social trend seems to closely resemble that of other species of deer (ex ; Linsdale and Tomich 1953, Severinghous and Cheatum 1956, Ito 1969).

SOCIAL INTERACTIONS

The number of behaviour patterns used by different antler class bucks are summarized in Table 3.

Buck-buck interactions

Head-up display (Schaller 1967) *:* This aggressive act is common among many cervids though different terms have been used (Strusaker 1966, Geist 1966, Miura 1976, Kucera 1978). This display is a rapid lifting of the head and the muzzle with the showing of incisors and was often accompanied by a snort. This was used by bucks toward other bucks and does. Nineteen of the 20 head-up displays (95.0%) were given by bucks of the greater than 50 cm antler class.

Thrashing and pawing : Bucks often used their antlers to violently thrash small shrubs. Thrashing was often performed in conjunction with pawing of the forefoot. These behavioural acts were not only used as an aggressive threat between bucks signaling readiness to fight, but also performed spontaneously without contact with other bucks where an agonistic context was not evident. The former case was observed 71 times. In 14% of the cases when the bucks confronting each other were within 1-5 m, and lasted from 5 to 30 sec. In 63.4% instances it was given by a buck when others approached

TABLE 3

NUMBER OF BEHAVIOUR PATTERNS USED BY DIFFERENT ANTLER CLASS BUCKS

Behaviour Patterns	Antler Class					
	More than 61 cm	60-51 cm	50-41 cm	Less than 40 cm	Spikes	Total
Head-up display	13	6	1			20
Head-down display	3	2				5
Thrashing bush with antler	52	25	8	2		87
Pawing by forefoot	29	18	7	1		55
Rubbing antler	12	4	1	1		18
Rubbing forehead	8	3	1			12
Rubbing preorbital gland	9	2				11
Rubbing neck	3	1	1	1		6
Sparring aggressively	7	8	1			16
Sparring play	21	17	11	9	4	62
Chasing	4					4
Circling	9	2	2	1		14
Parallel walk	6					6
Flehmen	21	8	3	2	2	36
Sniffing or muzzling	74	37	9	3	1	124
Following female	69	29	6	1		105
Erection penis	41	6				47
Mounting	23					23
Copulation	3					3

him within 10 m, and the rest were when other animals were 11-40 m away. The latter cases occurred fewer times (16 occasions). This act was performed by all antler class bucks, excepting yearlings during this period, however when frequency was correlated with antler class, the larger antlered bucks did it more frequently.

Wallowing was completely absent in the axis deer during the study.

Rubbing : A buck would occasionally rub his antlers, preorbital gland, or other regions of his face. The rubbing was accompanied by an erection of his penis and the expulsion of urine. This act was often interspersed in the thrashing and pawing sequence and was also performed in two contexts ; agonistic threat or not. Bucks performed this act without agonistic context in 44.4% of the observation.

Sparring : This act is typical of fighting among almost all ungulates. In this category of sparring encounters between two bucks in which they face each other with heads lowered, two bucks with antlers in contact, and two bucks pushing and occasionally clashing their antlers are included. This act, however, apparently involved different levels of aggressive intent ; ritualized and actual fight. Ritualized sparring matches had less aggressiveness and appeared as if they were playing with each others antlers, and was accompanied by grunts. Most participants in these matches were of different antler classes. Only four out of 31 matches observed involved equal size class, whereas 53.6% were of bucks one antler class apart, 28.6% of two classes apart, 10.8% of three classes apart. The greatest disparity involved two separate matches between a 65 cm antler class buck and a 30 cm buck. These matches were usually terminated when one of the participants turned and moved away and most of them showed no obvious victor. These matches lasted from 5 to 300 sec. with an average of 55.7 sec.

Actual fights were much less frequent and more violent than rirualized one, and usually of shorter duration ($\bar{X} = 7.2$ sec., $N = 8$). The loser ran away, and was chased by the victor. Seven of 16 participants in eight fights were of the greater than 61 cm antler class, the rest were of 51-60 cm class. Six of eight fights involved equal size class, and twice involved one class apart.

Chasing : Chasing was very rare in axis deer during the study, I observed such act only 4 times, all of which were preceded by actual fight and were performed by bucks of the greater than 61 cm antler class. Such scarcity of this act may be related to the fact that bucks make no attempt to establish and defend a territory.

Circling and parallel walk : These acts were observed 10 times, and almost always preceded an actual fight. In all of them one buck approached another, thrashing or rubbing its antlers on vegetation. The second buck would respond by thrashing or rubbing and the two would approach closer and continue to thrash. When near each other the animals would circle slowly around one another, or both would walk parallel within 1 to 10 m in the 'crouch' posture (Cowan and Geist 1961). Self-grooming or grazing displacement acts were also observed during such encounters.

Doe-buck interactions

Flehmen : This is a highly stereotyped act in many ungulates (Dagg and Taub 1970), and its frequency might be correlated with the rut. Most of them were accompanied by sniffing or licking doe's urine. 53 per cent of flehmens occurred during or just after urination by a doe, and the rest occurred after sniffing ground with fresh urine. Flehmen was observed in all classes of bucks, but was most commonly seen bucks of greater than 50 cm antler classes (80.5%). Spike and the less than 40 cm antler class bucks performed only twice respectively (11.2%). Mean duration of flehmen was 21 sec. (N = 36) with range of 10-30 sec.

Sniffing or muzzling: A buck would sniff or muzzle at the perineal region of does whenever he entered a group containing does or encountered a doe. The larger bucks sniffed significantly more often than the smaller bucks. A total of 124 sniffings observed, 59.7 per cent were performed by bucks of greater than 61 cm antler class, 29.8 per cent were 51-60 cm, 7.26 per cent 41-50 cm, 2.42 per cent less than 40 cm.

Following: After sniffing, bucks often followed or attempted to remain with a doe as she moved about. This acts resembles 'tending' described by McHugh (1958) for American bison. Although bucks of all antler classes, excepting spikes followed does, the frequency was significantly related to antler class. Following was performed by bucks of more than 51 cm antler classes in 93.3 per cent of the observations.

Following of does was usually performed by a single buck (95.0%), and he tried to prevent others from doing so by aggressive acts, such as head-up display, snorting, pawing, or thrashing, but on five occasions several bucks (2-5 animals) were seen following a doe. On these occasions, they rushed at a doe at full speed and they struggled for the doe by clashing with each other. It was my impression that such difference of following by bucks might be dependent on the state of receptivity of the doe, and the doe followed by several bucks seemed to be in oestrus or approaching it.

Bucks of axis deer never showed 'herding behaviour' described by Struhsaker (1967) for the elk, Lincoln *et al.* (1970) for the red deer, and Miura (1976) for the sika deer, in which they make an attempt to collect and retain a number of does. Bucks moved over a wide range and joined many groups, apparently in search of receptive does. When a buck entered a group containing does, he showed courtship behaviour toward a doe individually, and then he followed and tended her if she was in heat. As a result of such acts, they generally left the group and formed a temporary pair (tending bond ; McHugh 1958) until copulation was completed. Thus, there was no indication of a tendency by bucks to form or defend 'harem' group. Rather, tending bond system is accepted in axis deer.

Mounting and copulation: If a doe stopped moving and did not try to escape from sniffing by a buck while being followed, the buck would mount, straddling the doe's back with his hindlegs on the ground. Multiple mounts occurred during all three copulations observed, the number of mounts were three, five, and 15 respectively. All of them were performed by bucks of greater than 60 cm antler class. Copulation involved one thrust of a successful mount with the buck's feet leaving ground, the loin pushing forward, and throwing back his head for a moment. She was often forced several metres forward by his movement. Following copulation, tending by the buck ceased.

Diurnal variations of social interactions

The data on diurnal variations in frequencies of buck-buck and doe-buck interactions are summarized in Fig. 2. This figure demonstrates that there are two obvious peaks of two interactions respectively, one in the morning (0600-0700 hrs.) and one in the late afternoon. The afternoon peak of buck-buck interaction occurred earlier than that of doe-buck interaction. In spite of a slight lag of the peaks, the frequencies of two interactions which showed a biomodal pattern were very closely similar to each other.

Vocalization

Bucks would emit a variety of sounds for example, bellows (Schaller 1967), moans, barks,

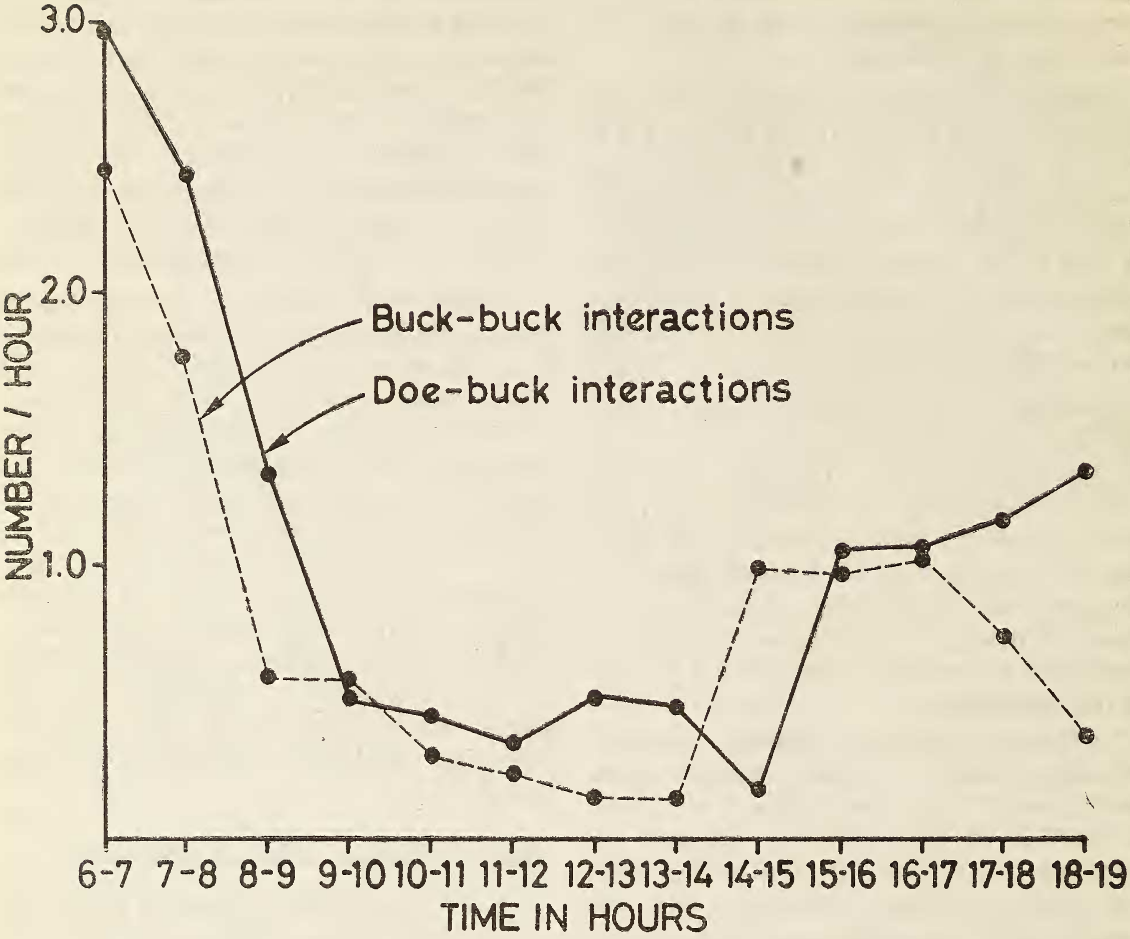

Fig. 2. Number of buck-buck and doe-buck interactions per hour of the axis deer in Guindy Sanctuary.

grunts and snorts. Bellows were the most common sound in this period and were emitted only by adult bucks. 98.0 per cent of the observations were emitted by the 51 cm antler class bucks. Every instance of this vocalization was recorded and diurnal variation was examined (Fig. 3). This sound could be heard at any time of the day, but most often in the morning and in the evening. The impression was gained that the frequency of this vocalization was deeply influenced by the number of buck-buck or doe-buck interactions.

Moans were also emitted only by adult bucks of greater than 50 cm antler class. Perhaps a production of this sound might be closely related to dominance rank among bucks. On 14 occasions mixed groups containing several known bucks of greater than 50 cm antler class were observed occupying the same areas at different times, only one of the bucks usually emits this sound, and he frequently showed sexual behaviour toward the does. This buck appeared to be the dominant among them according to the observations on aggressive

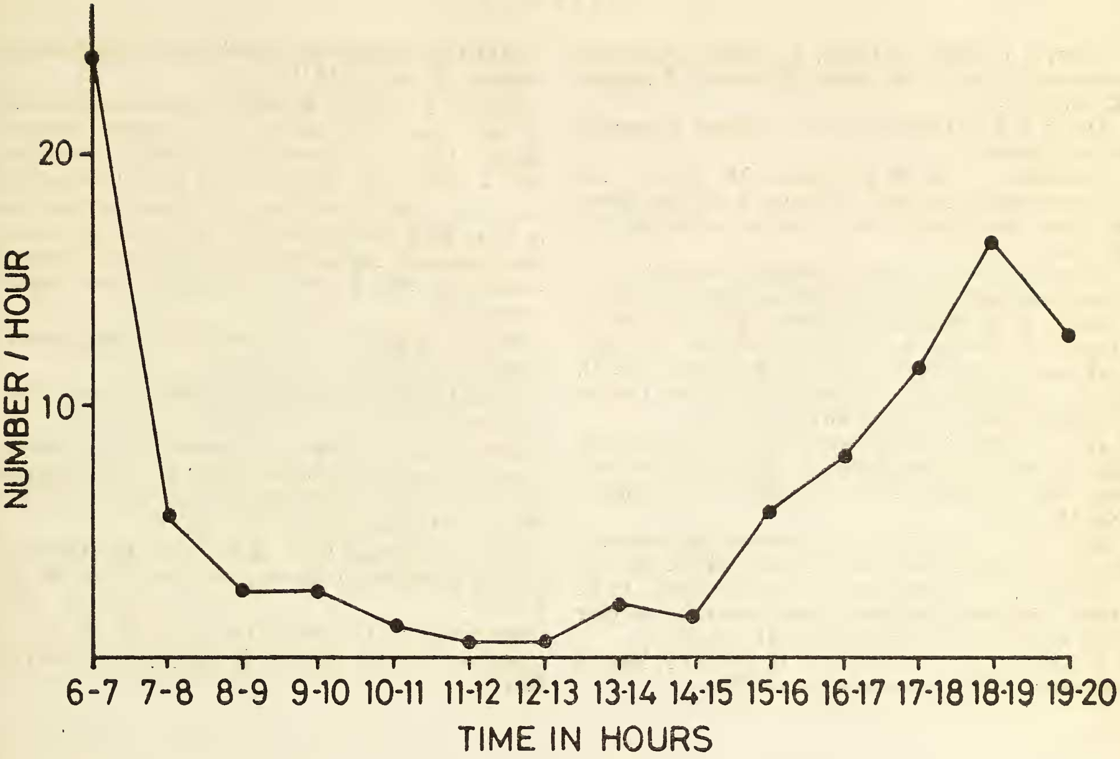

Fig. 3. Number of bellows per hour of the axis deer in Guindy Sanctuary.

interactions. Other bucks seemed to be tolerated being in the group unless they advertised themselves by emitting this sound. Other vocalizations could not be recorded quantitatively.

ACKNOWLEDGEMENTS

I am greatly indebted to Mr. T. Jeyadev, Chief Conservator of Forest, Madras, Mr. V. M. Narasimhan, Wildlife Warden, Madras, and Mr. K. S. Krishnan, Superintendent of Guindy Park for assistance in many ways for my fieldwork. I extend thanks to Dr. K. Y. Salih and Mr. A. Batcha, University of Cochin for advice and criticism of the manuscript. I would also like to thank Dr. V. Krishnamurthy, Forest Veterinary Officer, Madras and Mr. T. Unnikrishnan, Forest Range Officer, Madras for their advice throughout the study.

REFERENCES

COWAN, I. MCT. & GEIST, V. (1961): Aggressive behaviour in deer of the genus *Odocoileus*. *J. Mamm.* **42** (4): 522-526.

DAGG, A. I. & TAUB, A. (1970): Flehmen. *Mammalia* **34** (4): 686-695.

EISENBERG, J. F. & LOCKHART, M. (1972): An ecological Reconnaissance of Wilpattu National Park, Sri Lanka. *Smithsonian Contributions to zoology* No. 101, pp. 118.

GEIST, V. (1966): Some ethological observations on North American Cervids. *Zool. Beitrage* **12** (2): 219-251.

GRAF, W. & NICHOLS, L. (1966): The Axis deer in Hawaii. *J. Bombay nat. Hist. Soc.* **63** (3): 629-734.

HARDIN, J. W. SILVY, N. J. & KLIMSTRA, W. D. (1976): Group size and composition of the Florida key deer. *J. Wildl. Manage.* **40** (3): 454-463.

ITO, T. (1969): Ecological studies on the Japanese deer on the Kinkazan Island. I. The distribution and population structure. *Bull. Mar. Biol. Stat. Asamushi* No. **13**: 57-62.

KUCERA, T. E. (1978): Social behaviour and breeding system of the desert mule deer. *J. Mamm.* **59** (3): 463-476.

LINCOLN, G. A. YOUNGSON, R. W. & SHORT, R. V. (1970): The social and sexual behaviour of the red deer stag. *J. Reprod. Fert.* Suppl. No. **11**: 71-103.

LINSDALE, J. M. & TOMICH, P. Q. (1953): A herd of mule deer. Univ. California Press. pp. 576.

MCHUGH, T. (1958): Social behaviour of the American buffalo. *Zoologica* **43** (1): 1-40.

MIURA, S. (1975): Ecological studies on Sika deer in Nara Park with reference to spartial structure. *Annual Report of Nara Deer Research Association* No. **2**: 47-61. (In Japanese with English summary).

——— (1976): Sociological studies on Sika deer in Nara Park with referene to individual distribution and behaviour. *Annual Report of Nara Deer Research Association* No. **3**: 3-41. (In Japanese with English summary).

PRATER, S. H. (1971): The Book of Indian Animals. Bombay (Third ed.) pp. 324.

SCHALLER, G. B. (1967): The Deer and the Tiger. Chicago, pp. 370.

SEVERINGHAUS, C. W., & CHEATUM, E. L. (1956): Life and times of the white-tailed deer. In TAYLOR W. P. (Ed.) The deer of North America, 57-186. The Wildlife Manage. Instit., Washington.

SHARATCHANDRA, H. C. & GADGIL, M. (1975): A year of Bandipur. *J. Bombay nat. Hist. Soc.* **72** (3): 623-647.

STRUHSAKER, T. (1967): Behaviour of elk (*Cervus canadensis*) during the rut. *Z. Tierpsychol.* **24** (1): 80-114.